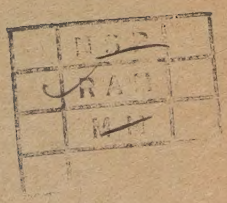
ANNUAL REPORT

of the

WEST AFRICAN RICE RESEARCH STATION



1956

ADMINISTERING AUTHORITY

THE SIERRA LEONE GOVERNMENT

Director of Agriculture:

J. W. D. GOODBAN, O.B.E., M.A., DIP.AGRIC., A.I.C.T.A.

SENIOR STAFF

At 31st December, 1956

Officer in Charge:

H. D. JORDAN, B.SC., A.R.C.S., A.I.C.T.A.

Agricultural Officer:

R. C. KNILL, B.SC., D.T.A.

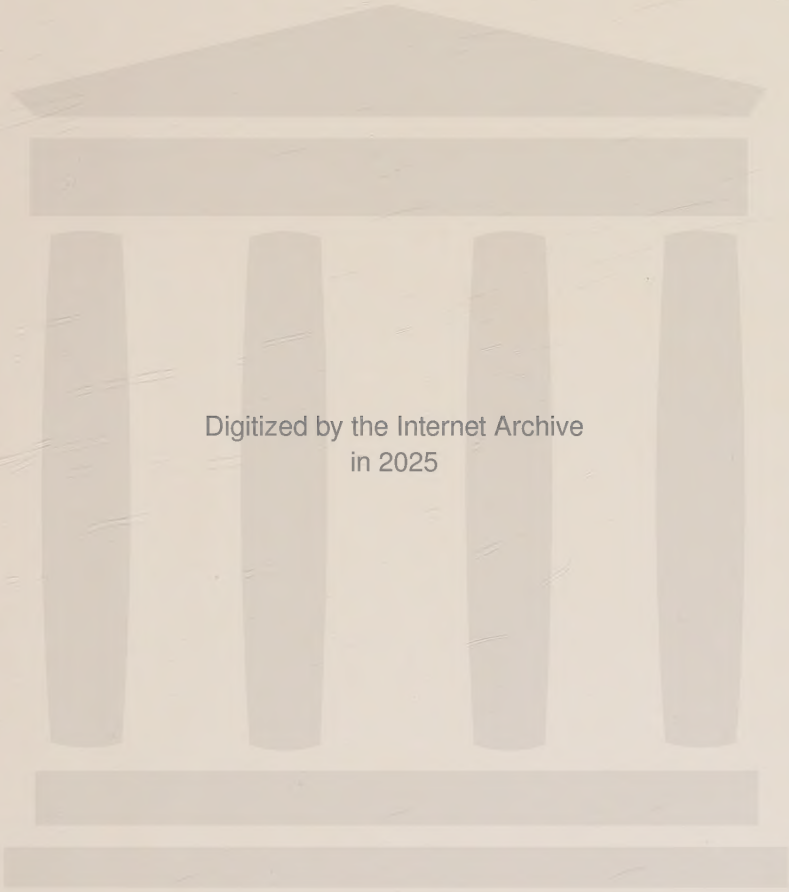
Botanists:

E. H. ROBERTS, B.SC., PH.D.

R. Q. CRAUFURD, B.SC.

Soil Microbiologist:

M. G. R. HART, B.SC., PH.D.



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WEST AFRICAN RICE RESEARCH STATION
A corner of the laboratories

ANNUAL REPORT

of the

WEST AFRICAN RICE RESEARCH STATION

1956

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INTRODUCTION

It can now be said that the West African Rice Research Station at Rokupr is more or less fully established and embarked on a programme designed to improve rice cultivation in the West African territories. It was in 1947 that proposals were first put forward for the enlargement of the existing rice station of the Sierra Leone Department of Agriculture to serve the research needs for rice of all four countries, but it was not until 1951 that funds became available, partly under the Colonial Development and Welfare Act and partly from the four territories concerned, and a start could be made on the programme of construction. Delays in construction and in the appointment of the research staff have meant that hitherto it has not been possible to do much more than continue and consolidate existing lines of research, but by the beginning of 1956 major construction was completed and the staff position much improved.

Prior to 1947 the station had been, since its inception in 1934, carrying out valuable work on rice for the Sierra Leone Department of Agriculture, largely by the determination of the best cultural practices for local conditions and by the improvement of rice yields by introduction and selection, though with staff limitations it was not possible to undertake research on the many other problems which became apparent during this time. In the earlier stages this work was largely concentrated on rice growing on the tidal mangrove lands of the Scarcies rivers, on which Rokupr is situated, but many of the results obtained were later successfully applied to the inland valley swamps and riverain flood plains as development of these was undertaken by the Department of Agriculture. The background of knowledge obtained during this period continues to be of great assistance in the present research programme.

Although the station now considers the research needs of all four West African territories it is for convenience administered by the Sierra Leone Government through the Director of Agriculture, and the Officer-in-Charge of the station is a member of the Agricultural Department.

ADMINISTRATION

STAFF

Senior Staff

Mr. H. D. Jordan continued as Officer-in-Charge throughout the year until he went on leave in early December. Mr. E. H. Nichols, Senior Agricultural Officer in the Sierra Leone Department of Agriculture, was then posted to Rokupr as relief.

Mr. R. C. Knill, Agricultural Officer, arrived in August to take charge of the Agronomy section and Station management. Prior to that time the Officer-in-Charge undertook these duties with assistance from the research staff.

The arrival of Dr. M. G. R. Hart, Soil Microbiologist, in January completed the research staff of the Soil Science section, but in August Dr. T. E. Tomlinson, Soil Chemist, resigned his appointment and there was a vacancy for the remainder of the year. Routine chemical work has continued under the supervision of Dr. Hart.

Staff of the Botany section has been at full strength, both Dr. E. H. Roberts and Mr. R. Q. Craufurd being at the station throughout the year.

Junior Staff

There has been considerable improvement during the year on all sides.

Clerical staff are now at full strength and with a satisfactory standard of typing it has been possible to issue several reports and bulletins.

The appointment of two more Laboratory Assistants has brought the laboratory junior staff to full strength, and the field staff position remains satisfactory.

Unestablished staff and labour averaged 150 through the year.

PUBLICATIONS

Quarterly Progress Reports, in cyclostyled form, have continued to be issued. The Annual Report for 1954 was received from the printer at the close of the year and has been distributed. The Annual Report for 1955 was prepared in draft form and cyclostyled copies circulated to the contributing governments.

Six further Periodic Scientific Reports were produced, all based on work by the Soil Chemist. They are for limited distribution and are summaries of work in progress, prepared at convenient stages in this work.

The first of a series of bulletins was issued. These are reprints of old surveys and reports on rice growing, and are issued in cyclostyled form for limited distribution within West Africa.

Five papers have been accepted for publication as follows:

" Relationship between Mangrove Vegetation, Soil Texture and Reaction of Surface Soil after Empoldering Saline Swamps in Sierra Leone." T. E. Tomlinson. Tropical Agriculture, January, 1957.

" Changes in a Sulphide-containing Mangrove Soil on Drying and their Effect upon the Suitability of the Soil for the Growth of Rice." T. E. Tomlinson. Empire Journal of Experimental Agriculture, April, 1957.

" Hybridization of Rice." H. D. Jordan. Tropical Agriculture, April, 1957.

" Crabs as Pests of Rice on Tidal Swamps." H. D. Jordan. Empire Journal of Experimental Agriculture, July, 1957.

" A Seasonal Variation of the Surface pH value of some Rice Soils of Sierra Leone." T. E. Tomlinson. Tropical Agriculture, October, 1957.

TOURING AND VISITS

With the improvement in the staff position it has now been possible for visits to be made to the other contributing territories. Mr. H. D. Jordan attended the first meeting of the West African Standing Advisory Committee for Agricultural Research which was held in Accra in April, when he was able to discuss rice problems in the Gold Coast and to visit the experimental irrigation station at Kpong. In May he spent three weeks in Northern Nigeria, visiting the rice station at Badeggi and seeing a number of areas being developed for rice cultivation. He also attended a meeting of the Technical Committee on Agriculture of the Nigerian Council of Natural Resources, which meeting was largely concerned

with reviewing rice work in Nigeria and discussing the co-ordination of research work on rice in West Africa. In November Mr. Jordan spent ten days in the Gambia, visiting the Gambia Rice Farm at Sapu and riverain and coastal potential rice lands.

Mr. R. Q. Craufurd spent a month in Northern Nigeria in October, when he was able to visit most of the major rice growing areas.

Messrs. H. D. Jordan, E. H. Roberts and T. E. Tomlinson visited French Guinea in January and spent some days at the Rice Research Station at Koba, as well as visiting a number of coastal areas which are undergoing large-scale reclamation for rice growing.

Within Sierra Leone, Dr. Tomlinson and Dr. Hart paid a number of visits to mangrove areas and Dr. Roberts spent ten days in the southern part of the country examining the extensive fresh water, deeply flooding grasslands. Mr. Craufurd paid two visits to the central riverain flood plains.

VISITORS

His Excellency the Governor of Sierra Leone, Sir Maurice Dorman, K.C.M.G., and Lady Dorman honoured the station by a brief call in September.

The Right Honourable John Hare, O.B.E., Minister of State for Colonial Affairs, accompanied by Mr. C. G. Eastwood, C.M.G., of the Colonial Office, spent one night at Rokupr in March, and Professor G. E. Coates of Durham University, accompanied by Dr. E. Downing of Fourah Bay College, visited the station for a few days in May.

Mr. A. Pickles, Secretary for Forestry and Agriculture Research, West African Inter-Territorial Secretariat, Dr. F. M. Milam, American Agricultural Attaché for West Africa, Mr. P. C. Chambers, Director of Agriculture, Northern Nigeria, Mr. T. E. Phillips, Deputy Director of Agriculture, Eastern Nigeria, and Mr. B. C. Walson of the Eastern Nigeria Department of Agriculture all spent a few days at the station during the year.

M. C. Dumont and M. F. le Cochec from the Rice Research Station at Koba in French Guinea visited Rokupr in November.

Dr. G. W. Ivens of the Colonial Pesticides Research Unit at Arusha in Tanganyika spent six weeks at Rokupr in April and May, when he laid down a number of experiments on the use of arboricides in killing mangroves.

MANAGEMENT AND MAINTENANCE

BUILDINGS

Construction of four of the outstanding Junior Service quarters was started by the Public Works Department during the year, but apart from this no further major construction was carried out. The old condemned Senior Service quarter has been largely demolished, but rebuilding on the site awaits approval of a small new capital construction programme.

A small extension was made to the drying floors for experimental material, and a temporary servants' room at the house of the Officer-in-Charge was replaced by one of permanent construction. This house was also redecorated throughout at the end of the year.

Minor repairs were carried out to all buildings; in particular the roofs of the stores were painted and the outside walls redecorated.

SERVICES

The Station water supply continued to be managed by the Sierra Leone Public Works Department and to supply the town of Rokupr. The valley from which the water is pumped silted considerably and at the end of the dry season the water became very dirty. A scour valve is fitted to the dam, and it is hoped that proper use of this during the rainy season will clear the silt and obviate further trouble of this kind.

The Sierra Leone Electricity Department continues to manage the Station electricity supply. A phase balancer has been installed and this has reduced voltage fluctuation to some extent. However, sensitive apparatus is still affected by minor fluctuation, and it is apparent that with a small electricity system this will always occur and it will be necessary to run such apparatus from batteries.

VEHICLES AND MACHINERY

The Bedford 3-ton lorry was in use throughout the year for station and general transport. It is proposed to obtain a Ferguson tractor and trailer for the heavier station transport and a Land Rover for touring purposes.

The diesel launch was in good order throughout the year, but the T 20 runabout launch suffered from numerous mechanical defects and was out of action for much of the time. A locally-made boat was in use for ferrying officers and labourers across the river.

The M.G.6 tractor and plough were used for ploughing the farm, but the M.G.5 tractor gave trouble and has been transferred to the workshops of the Sierra Leone Department of Agriculture for a complete overhaul. The Hayter motor scythe has proved more efficient than the Allen Autoscythe for cutting long grass. The three motor mowers, in addition to hand mowers, were used for the upkeep of the Station lawns. It is proposed to obtain a gang mower to use with the Ferguson tractor for this purpose.

The Sierra Leone Department of Agriculture has continued to give advice and assistance when required in the maintenance and repair of all machinery. This is normally carried out in the Station workshops.

STATION UPKEEP

General repair and maintenance of all Station roads has been continued.

A programme of major repair and reconstruction of all bunds and drains on the swamp farm was started at the end of the year and this will be completed.

MISCELLANEOUS CROPS AND STOCK

Crops

Crab trapping having now stopped, the remaining cassava was cleared and sold and the areas are being laid down to grass.

A good supply of vegetables was maintained through the year. The garden has now been closed and the area re-laid out for the upland rice collection.

The plantation of Angola Oil Palms is being maintained as a source of seed for the Department of Agriculture's extension programme. Records of yields of individual trees are being kept for information.

The supply of fruit for staff use has again been satisfactory and the preparation of sites and planting of fruit trees at all staff quarters has continued.

Stock

The herd of Ndama cattle has now been disbanded and transferred to the headquarters of the Sierra Leone Department of Agriculture. Three calves were born during the year and five animals were slaughtered.

The pair of breeding pigs has also been transferred and only a few pigs for fattening will be kept in future. Six animals were sold and slaughtered during the year.

The remaining ducks have been sold.

WEATHER

As in 1955, the total rainfall for the year was above average, the distribution being more extended through the year. In particular, June approached the record of 24 inches of 1939, the only previous time that more than 20 inches has been recorded during the month. In April, a fall of 2·78 inches in 24 hours is a record intensity for the month. There was slight harmattan during January. Temperatures were a little below average, the mean maximum for December in particular being almost a degree below the previous low record for this month (in 1940). Full meteorological records for Rokupr for the year are given in Appendix A.

AGRONOMY

General nursery and planting practices remain as described in earlier reports.

Spraying of bunds and drains with a technical benzene hexachloride suspension prior to transplanting was continued as a routine measure against crabs. Damage by crabs occurred on a minor scale but was insignificant compared to the damage caused in 1953 and earlier, before spraying was started.

Weather conditions were favourable to growth throughout the growing season, but yields in general were slightly below average. Table 1 shows yields of blocks that were in use for multiplication, as compared with the yields over the previous six years. The fourteen-acre farm on the opposite side of the river was this year planted with later varieties and bird damage was negligible. Yields compared with those on the main experimental farm.

644 bushels (of 60 lbs. weight) of seed were produced as follows:

B.G. 79	121 bushels
Toma 112	94 ,,
D 99	87 ,,
Ngasein 57	62 ,,
Lead	60 ,,
India pa lil 46	60 ,,
Kavunginpoothala 12	56 ,,
Bolo 108	52 ,,
Sughandi	35 ,,
Indo-China 53	17 ,,

Most of this seed was distributed locally by the Sierra Leone Department of Agriculture, but over sixteen bushels of nine varieties were sent to the Gambia.

Mechanical purity of the seed was maintained at a high standard. Genetically pure seed from the bagging system described last year is not yet ready for distribution. This system, which is designed to prevent cross pollination and enable genetically pure stocks to be maintained, has been extended, and a total of nine varieties are now maintained as

TABLE 1

Yields of multiplication blocks—1956
(*in lbs. paddy per acre*)

Block	1950	1951	1952	1953	1954	1955	1956
1	3,250	1,760	—	1,060	1,050	2,060	1,660
2	2,270	1,730	1,840	870	—	1,630	1,640
7	480	2,200	2,370	1,580	1,740	1,740	2,550
8	—	—	2,020	—	1,480	—	1,400
10	1,740	970	2,650	1,170	2,200	1,870	1,550
11	1,220	580	2,370	1,420	2,200	—	2,340
13	2,680	960	2,540	460	2,140	1,820	1,300
14	2,670	1,000	2,480	1,760	1,640	1,280	1,300
16	2,030	440	2,360	—	—	1,760	510
17	3,520	580	1,760	—	—	1,410	1,330
28	1,710	1,660	1,520	860	2,220	2,100	1,690
30	—	610	1,600	840	650	1,170	420
31	1,680	1,830	1,170	—	1,510	2,600	1,550
32	930	600	500	1,930	530	1,330	1,020
33	840	1,540	1,210	—	—	1,770	1,260
34	800	780	1,970	1,170	700	2,060	1,630
35	1,070	1,360	1,320	—	1,770	1,640	1,260
36	790	910	1,460	440	550	2,090	1,660
37	1,440	1,100	1,150	1,150	1,560	1,330	1,170
38	—	780	1,190	470	760	1,570	1,250
39	1,260	660	1,010	860	960	1,170	650
41	1,750	1,350	1,720	1,210	1,400	1,290	2,120
42	—	980	1,370	810	1,320	1,860	1,810
43	2,580	2,210	2,440	1,090	2,280	2,260	2,530
44	1,170	1,430	1,420	950	—	2,540	1,090
45	1,530	1,140	1,670	1,000	1,540	2,570	920
46	—	610	1,380	800	1,990	2,410	1,340
47	—	1,100	910	360	770	1,380	1,130
48	—	1,130	1,270	380	450	1,140	360
49	—	880	910	370	860	890	400
50	2,970	2,530	520	1,370	2,290	1,310	1,810
51	1,980	1,360	1,280	1,860	2,400	2,950	1,450
52	870	1,160	2,430	1,160	2,180	2,370	1,870
53	1,320	1,190	1,590	1,550	1,640	1,140	1,330
54	1,210	1,130	1,820	650	1,220	2,210	1,030
55	—	1,080	1,650	590	870	830	750
56	—	880	690	670	540	620	940

Note.—Blocks 1 and 2 had heavy fertilizer application in 1950.
Blocks 10, 13 and 14 were water controlled in 1950 and 1951.
In 1951 and in 1953 crabs caused considerable damage.

Genetic Stocks: Lead, B.G. 79, D 99, Ngasein 57, Toma 112, Bolo 108, India pa lil 46, Kav. 12 and Indo-China 53. In two years time all seed of these varieties distributed will be not more than four generations away from a bagged plant, and this bagged plant will be one of the progeny of plants which will have been bagged in every preceding generation back to the time when the scheme started.

CRAB INVESTIGATIONS

No further work was carried out on control of crabs, but daily collections were continued in order that a clearer picture of the breeding habits of the crabs could be formed from two years' observations.

Examination of the collection figures for the whole two-year period confirms that there is a marked fall off in the proportions of females carrying eggs in the months from July to October. This time of the year is the rainy season, and comparison of the figures with those of mean daily temperature shows that this fall is related to a fall in temperature at that time.

During the dry season it became apparent that, in addition to the breeding cycle dependent on high spring tides, there was another, independent, cycle of egg production. No correlation could be found between this cycle and any external factor, and it is thought that it may be due to an internal breeding rhythm of the crabs. A detailed examination of all the records shows that egg carrying fluctuates in the dry season on an eleven week cycle, and that superimposed on this is a similar fluctuation on a four week cycle associated with high spring tides. The fluctuation in the proportion of males to females noted in 1955 was found to be non-significant when two years' figures were examined.

Full details of the work have been written up and accepted for publication.

ARBORICIDE AND HERBICIDE TRIALS

The results of the trials reported in the 1955 Annual Report were sufficiently encouraging to warrant an extension of the work, and Dr. G. W. Ivens of the Colonial Pesticides Research Unit at Arusha in Tanganyika laid down a number of trials in the vicinity of Rokupr in early 1956. These were on *Avicennia* and *Rhizophora* mangrove and on the salt-resistant grass, *Paspalum vaginatum.*

Avicennia nitida

The butyl ester of 2,4-D (2,4-dichloro-phenoxyacetic acid) was tested at concentrations of 0·5, 1, 2 and 4 per cent (acid equivalent) in diesel oil both on frilled and unfrilled trees, each treatment being applied to ten trees. 2,4,5-T (2,4,5-trichloro-phenoxyacetic acid) butyl ester was also tested at the same concentrations on unfrilled trees and diesel oil alone was applied with and without frilling. For comparison with the 2,4,5-T butyl ester a low volatile ester was applied at 0·5, 1 and 2 per cent in diesel oil and the butyl ester was tested mixed with water at 1 and 4 per cent. A few frilled trees were also treated with 2 and 10 per cent solutions of amino-triazole. The solutions were applied by an Oxford precision sprayer to the basal 12 to 18 inches of the trunk and an average of 200 ml. per tree was required to wet this zone thoroughly. In addition to the basal bark sprays it was considered worth while trying 2,4,5-T applied to the ground underneath the trees where it could be absorbed by the pneumatophores. Concentrations of 0·5 and 2 per cent in oil were tested in this way at a rate of 10 gallons per acre and 0·1 and 0·4 per cent in water at 50 gallons per acre. CMU (3-(4-chlorophenyl)-1, 1-dimethylurea) was also tested as a ground spray at rates of 4 and 20 lbs. per acre in water.

The first sign of an effect on the trees was noticed about three weeks later, when it was observed that 2 per cent and 4 per cent 2,4-D and 2,4,5-T applied in diesel oil as basal trunk sprays had caused a certain amount of leaf yellowing. Results of further observations are summarized in Table 2.

It will be noted that with the basal trunk sprays 2,4-D produced an effect on the unfrilled trees more quickly than 2,4,5-T and was also effective when the trunks were frilled. Two months after treatment there was marked yellowing of the foliage of the 2,4-D treated trees, which was more pronounced with the higher concentrations, and some leaves had fallen. The only soil treatment to have produced an effect after two months was CMU at 20 lbs. per acre.

After seven months varying degrees of leaf fall had taken place. Again 2,4-D was more effective than 2,4,5-T and at the 4 per cent rate almost complete defoliation had occurred. Although less effective, 2,4,5-T

in oil had nevertheless caused considerable defoliation, both as the butyl ester (Treatments 7-10) and as a low volatile ester. The butyl ester applied in water as an emulsion produced moderate but only temporary defoliation, and there was considerable leaf fall with the higher rate of amino-triazole. The higher rate of CMU applied to the ground was very effective, but none of the other soil treatments had more than temporary effects.

TABLE 2

The results of arboricide treatments on Avicennia nitida

Treatment	No. treated	Months after treatment: 2 — Leaf yellowing	7 — Degree defoliation	12 — % defoliation	12 — No. dead	12 — No. probably dying
Basal trunk sprays						
1 Diesel oil No frill	10	0	x	14	0	0
2 Diesel oil Frill	10	0	x	9	0	7
3 2,4-D ester in oil ½%	10	xx	xxx	39	0	0
4 2,4-D ester in oil 1%	10	x	xxx	49	0	0
5 2,4-D ester in oil No frill 2%	10	xxx	xxx	65	2	0
6 2,4-D ester in oil frill 4%	10	xxx	xxxx	96	8	1
7 2,4,5-T ester in oil ½%	10	x	xxx	6	0	0
8 2,4,5-T ester in oil 1%	10	0	xx	11	0	0
9 2,4,5-T ester in oil No frill 2%	10	x	xxx	29	0	0
10 2,4,5-T ester in oil frill 4%	10	0	xxx	40	1	3
11 2,4-D ester in oil ½%	10	xx	xxx	59	1	8
12 2,4-D ester in oil 1%	10	xx	xx	47	0	10
13 2,4-D ester in oil 2%	10	xx	xxx	89	6	4
14 2,4-D ester in oil Frill 4%	10	xxx	xxxx	94	7	2
A 2,4,5-T ester emulsion 1%	10	0	xx	11	0	0
B 2,4,5-T ester emulsion Frill 4%	10	x	xx	11	0	2
C 2,4,5-T L.V. ester in oil ½%	10	x	xx	4	0	0
D 2,4,5-T L.V. ester in oil 1%	10	xx	xxx	18	0	0
E 2,4,5-T L.V. ester in oil No frill 2%	10	xx	xxx	15	0	0
F Amino-triazole in water 2%	10	0	0	22	0	2
G Amino-triazole in water Frill 10%	10	0	xxx	32	0	2
Spray applied to ground and pneumatophores						
H CMU 4 lb./acre	5	0	xx	38	0	0
I CMU 20 lb./acre	5	xxx	xxxx	100	5	0
J 2,4,5-T in oil ½ lb./acre ½%	5	0	xx	14	0	0
K 2,4,5-T in oil 2 lb./acre 2%	5	0	xx	14	0	0
L 2,4,5-T emulsion ½ lb./acre 0.1%	5	0	xx	8	0	0
M 2,4,5-T emulsion 2 lb./acre 0.4%	5	0	xx	36	0	0

L.V.—low-volatile (methyl iso-butyl carbinol) ester.
x.—slight yellowing or defoliation.
xx.—moderate yellowing or defoliation.
xxx.—considerable yellowing or defoliation.
xxxx.—100% yellowing or defoliation.

Estimates of the degree of defoliation made after twelve months suggest that the 2,4,5-T treated trees have largely recovered from the effects of treatment, and even with the highest concentration tested (4 per cent acid equivalent) only one out of ten treated trees is dead. With 2,4-D larger numbers are dead and where applied without frilling eight trees out of ten are leafless with the bark dry and flaking off. None of the dead trees has produced any regeneration from below the treated zone. As estimated by the degree of defoliation, the effects of 2,4-D with and without frilling are very similar. Where the trunk was frilled, however, nearly all the trees still in leaf look as though they will die, in that a circle of bark in the region of the frill is dead and there is no connecting strip of living bark across the frill. In some cases the bark below the frill is discoloured and obviously unhealthy although that above the frill still appears normal. Similarly, many of the frilled trees treated with diesel oil alone look as though they will eventually die, although so far they have not lost an appreciable number of leaves. Frilling combined with water based sprays of 2,4,5-T or amino-triazole has been much less effective than with the oil based sprays. CMU is the only chemical to have been effective at all in the soil treatments, and all the trees receiving the high rate (20 lbs. per acre) are dead.

Table 3 shows the overall percentage kills of trees in different size classes (treatments 1 to 14 only). There is no evidence that small trees are any more easily killed than large ones.

TABLE 3

The effects of 2,4-D and 2,4,5-T treatments on Avicennia trees of different sizes

Basal diameter of trunk	*Total treated*	*Total dead*	*Percentage kill*
0– 6 inches	21	10	45
6–12 „	98	41	42
12–18 „	17	8	47
Over 18 „	4	1	25

Rhizophora racemosa

Diesel oil alone and 2,4-D in oil at 0·5, 1, 2 and 4 per cent were tested on both frilled and unfrilled trees and 2,4,5-T at the same concentrations on unfrilled trees alone. Again ten trees were given each treatment. The solutions were applied by means of a paint brush as it was impracticable to operate a sprayer among the dense tangle of prop roots surrounding the trees. The base of the main trunk above the highest prop root was treated; generally 6 to 10 feet above ground level. On a few trees one or two large prop roots descended from higher up the trunk and in these cases the roots themselves were also treated at an accessible level. An average of approximately 200 ml. of solution was applied to each tree but an appreciable amount of liquid ran down the trunk on to the prop roots, and it appeared that a lower volume would be sufficient to wet the desired zone adequately. Additional treatments were therefore applied using 2 per cent 2,4,5-T on frilled and unfrilled trunks at the rate of 100 ml. per tree. Other treatments tested were the low volatile ester of 2,4,5-T in oil at 0·5 and 2 per cent, 2,4,5-T butyl ester in water at 2 per cent and 2,4,5-trichloro-phenoxypropionic acid (2,4,5-TP) in oil at 1 and 4 per cent.

In general the results, which are shown in Table 4, are similar to those observed on *Avicennia*.

TABLE 4

The results of arboricide treatments on Rhizophora racemosa

	Treatment		Number treated	Months after treatment: 7	Months after treatment: 12		
				Degree defoliation	% defoliation	No. more than 90% dead	No. 50–90% dead
1	Diesel oil	No frill	10	0	0	0	0
2	Diesel oil	Frill	10	0	61	4	0
3	2,4-D ester in oil	½%	10	0	45	4	1
4	2,4-D ester in oil	1%	10	x	35	1	2
5	2,4-D ester in oil No frill	2%	10	xx	50	3	2
6	2,4-D ester in oil No frill	4%	10	xxx	82	7	1
7	2,4,5-T ester in oil	½%	10	0	0	0	0
8	2,4,5-T ester in oil	1%	10	0	26	0	3
9	2,4,5-T ester in oil No frill	2%	10	xxx	55	3	3
10	2,4,5-T ester in oil No frill	4%	10	xxx	62	5	1
11	2,4-D ester in oil Frill	½%	10	x	78	5	3
12	2,4-D ester in oil Frill	1%	10	xxx	70	4	2
13	2,4-D ester in oil Frill	2%	10	xxx	79	4	4
14	2,4-D ester in oil Frill	4%	10	xxx	73	5	2
A	2,4,5-T emulsion Frill		10	0	10	1	0
B	2,4,5-T L.V. ester in oil No frill	½%	10	0	19	1	1
C	2,4,5-T L.V. ester in oil No frill	2%	10	x	22	0	2
D	Low volume 2,4,5-T in oil 2%	Frill	10	xxx	71	4	3
E	Low volume 2,4,5-T in oil 2%	No frill	10	—	18	0	1
F	2,4,5-TP ester in oil No frill	1%	5	0	6	0	0
G	2,4,5-TP ester in oil No frill	4%	5	0	4	0	0

L.V.—low-volatile (methyl iso-butyl carbinol) ester.
x.—slight defoliation.
xx.—moderate defoliation.
xxx.—considerable defoliation.

Considerable defoliation had occurred after seven months with the higher rates of both 2,4-D and 2,4,5-T, but the final kill was somewhat greater with 2,4-D. The difference between the two chemicals was less marked with *Rhizophora* however. Frilling has again increased the effectiveness of the chemicals and on the frilled trees diesel oil alone has given a moderate degree of kill. With this treatment the table shows that four out of ten trees are almost entirely dead; four more of these trees still possessed leaves but had a ring of dead bark in the region of the frill and will presumably eventually die. With frilling a relatively low volume of 2,4,5-T in oil (100 ml. per tree) appears to have been as effective as a higher volume (200 ml. per tree as used for all the other treatments) while 2,4,5-T emulsion has had little effect. Without frilling, neither the low-volatile ester of 2,4,5-T nor 2,4,5-trichlorophenoxypropionic acid has been very effective.

It was very noticeable in this experiment that the most seriously affected trees were those which had no prop roots arising from above the treated zone of the trunk and no aerial roots descending from the lower branches into the mud. Such trees which had received one of the more effective treatments were generally completely dead, the upper

parts of the tree being leafless and the whole system of prop roots dried up and becoming brittle. Where there was an abnormally high prop root however, although in most cases this had been treated (without frilling), it was frequently noted that some of the lower branches appeared normal while the rest of the tree was dead. Similarly, where roots from the lower branches made contact with the ground, the branches from which they arose were generally normal. Aerial roots were most numerous on the smaller trees, though with a few larger trees they descended from a height of up to 40 feet, and the percentage kill of the smaller trees was markedly lower than that of the larger ones, probably for this reason. The overall percentage kills from treatments 1 to 14 with trees of different sizes is shown in Table 5.

TABLE 5

The effects of 2,4-D and 2,4,5-T treatments on Rhizophora trees of different sizes

Basal diameter of trunk	*Total treated*	*Total dead*	*Percentage kill*
0– 6 inches	45	8	18
6–12 „	49	12	24
12–18 „	29	15	52
Over 18 „	15	10	67

A small trial to test 2,4,5-T as an overall spray on *Rhizophora* gave no conclusive results. Trees treated with a 15 per cent solution in diesel oil at a rate equivalent to two gallons per acre appear normal after twelve months. Those receiving a 3 per cent solution at 10 gallons per acre have been affected to some extent in that many of the small branches on the side from which the wind was blowing at the time of application have died back for a distance of 2 to 3 feet. The majority of the branches however are unaffected. To obtain a reliable assessment of the potentialities of overall spraying this experiment would have to be repeated with more suitable spraying equipment.

Conclusions from Mangrove Experiments

It is evident from these experiments that ester formulations of 2,4-D applied in oil to the base of the trunk are the most suitable of the treatments tested for the eradication of both *Avicennia* and *Rhizophora* mangroves. 2,4,5-T, besides being more expensive, is less effective. Applied without frilling it appears that a concentration of 2,4-D of the order of 4 per cent is needed to obtain a high percentage kill. With frilling the concentration can be reduced at least to 2 per cent and probably to 1 per cent or even lower. With *Avicennia*, frilling is a very simple matter; with *Rhizophora*, it is considerably more laborious but nevertheless probably well worth while.

With the rate of application used in these trials (an average of 200 ml. per 10 inch diameter trunk) an acre of land bearing 100 trees would require approximately 5 gallons of oil and $\frac{1}{2}$ lb. acid equivalent of chemical if treated with a 1 per cent solution. There is some evidence that the rate of application could be further reduced without reducing the effectiveness of the treatment. Diesel oil alone combined with frilling has given fairly good results, but the addition of 2,4-D causes the trees to die more quickly and results in a more complete final kill.

With *Rhizophora* it is probably only worth treating the larger trees; those with a basal trunk diameter below about six inches can be cut down relatively easily. It will be necessary to ensure that any prop roots arising from the trunk above the treated zone are frilled and treated and that any aerial roots are cut.

The good results on *Avicennia* obtained with CMU at 20 lbs. per acre suggest that this chemical would be worth trial at lower rates of application. In the experiment described the spray was applied to the whole area of ground directly under the trees to cover the majority of the pneumatophores. This represented something like a half of the total area involved, and it is probable that a high kill could be obtained by treating a much smaller proportion of the total area. CMU, however, is much more expensive than 2,4-D and the rate of application would have to be cut down to something of the order of 1 lb. per acre of the total area to be as economical.

Paspalum vaginatum

This salt resistant grass can become troublesome when it is well established, when it becomes difficult to remove by hand cultivation. A trial of a number of possible grass killers was laid down on a dense area of *Paspalum* about 18 inches high. The chemicals tested were CMU, 3-phenyl-1, 1-dimethylurea (PDU), and 3-(3,4-dichlorophenyl)-1, 1-dimethylurea (DDU) at rates of 5, 10 and 20 lbs. per acre, and trichloroacetic acid (TCA) and dichloropropionic acid (Dalapon) at 20, 40 and 80 lbs. per acre. All were applied in 50 gallons of water per acre to unreplicated plots of one two-hundredth acre each. The results of various observations on this trial are shown in Table 6.

TABLE 6

The effects of various herbicides on Paspalum vaginatum

	Treatment		Months after treatment 1	2	6	12
			Degree scorching	*Degree scorching*	*Degree scorching*	*Estimated % reduction*
1	CMU	5 lbs./acre	0	0	x	10
2	CMU	10 „	0	—	—	10
3	CMU	20 „	0	0	x	10
4	PDU	5 „	0	0	0	0
5	PDU	10 „	x	0	0	0
6	PDU	20 „	xx	xx	xxx	40
7	DDU	5 „	0	0	0	0
8	DDU	10 „	0	0	0	0
9	DDU	20 „	0	0	0	0
10	TCA	20 „	0	—	—	0
11	TCA	40 „	xx	xxx	xxx	40
12	TCA	80 „	xx	xxxx	xxx	50
13	Dalapon	20 „	xxx	xxx	xxx	70
14	Dalapon	40 „	xxxx	xxxx	xxxx	95
15	Dalapon	80 „	xxxx	xxxx	xxxx	100

x.—appreciable scorching.
xx.—moderate scorching.
xxx.—considerable scorching.
xxxx.—100% kill.
Note.—Plots 2 and 10 were accidentally burned in July 1956.

Of the substituted urea derivatives it is evident that only PDU at 20 lbs. per acre has been at all effective. After six months the majority of grass on this plot had been killed but regrowth was taking place, and after twelve months there was again a complete cover. DDU produced no visible effect at all and CMU had only a slight effect after six months. The TCA treatments were somewhat more effective and 40 and 80 lbs. per acre gave good control for six months. After this time, however, regrowth took place and there was a complete cover of grass after a year. The most promising chemical tested was Dalapon. It appeared to act more quickly than TCA and even with the lowest rate tested gave good control for six months. Regrowth was less rapid than with TCA and after twelve months the grass had still not formed a complete cover on the ground. At the two higher rates the grass was completely killed and a year after application only a few scattered tufts had re-established themselves.

Further experiments are projected using lower rates of Dalapon and combining the treatments with burning and with cutting.

ESTIMATION OF YIELDS

Further estimations of the yields of the multiplication blocks were made as an extension of the work reported last year, which was carried out at the request of the Sierra Leone Department of Agriculture. Eye estimation was made by five observers, three of whom carried out last year's estimations, and their estimates were calibrated against true yields. Estimation by sampling using four one-square-yard samples per block as described previously was also made, and in addition a similar estimation using four one-square-yard circular samples was carried out for comparison.

Little difference was found between the two sampling methods, both giving an average estimated farm yield closer to the true yield than did last year's results. Statistical efficiency of the circular plot method was however higher than that of the square plot method.

Eye estimations, as last year, were as close or closer to mean true yield than were means of estimations made by sampling.

The mean farm yields as determined by the square plot method and by the eye estimations were adjusted using the appropriate calibrations determined in 1955. The results, however, gave no near approximations to true yield, and it is apparent therefore that these relatively simple methods will not be of any great practical use in the field for obtaining even an approximate estimation of yield.

BOTANICAL RESEARCH

The search for improved varieties of rice by introduction, selection and hybridization remains the principal work of the Botany section. It has now been possible, however, to undertake a few preliminary experiments on fundamental physiological problems which are of practical importance in the improvement work, as well as to expand the scope of this work itself.

INTRODUCTION AND TESTING OF RICE VARIETIES

There has been a considerable expansion of the programme during the year and requests were made to other countries for a large number of rice varieties which seemed as if they might suit West African conditions. One hundred and thirty-five of these arrived in time for sowing in 1956, and a list is given in Appendix B. Many of these varieties are reputed to be particularly suitable for special conditions. In addition a further

19 Sierra Leone rices were collected and grown for comparison with the standard varieties at Rokupr. The number of varieties in the swamp collection is now 440. Three of these, which are reputed to be dual purpose rices, were also included in the upland collection of 31 varieties.

The recording of the characters of all these rices occupied a large proportion of the time of both laboratory assistants and senior staff during the period of flowering and harvest. As time permits, this information will be transferred to a punched-card sorting system. Cards for this purpose have been designed and printed. Certain useful agricultural characters are very variable and have to be recorded for several years before full estimation of them can be obtained. One of these characters is tillering capacity and, to facilitate measurement of this character, the system has been started of planting one end of each observation plot with six rows of single plants spaced six inches apart, so that tiller counts could be made on the centre four rows.

In general the growth of the varieties in the collection was good, though certain plots were damaged by crabs. It was noted that, in many of the early varieties, flowering was very erratic and spread over a period of three weeks or more, and in a number of these cases each plant produced only one tiller. The reason for this is not clear, but the results of a successional sowing experiment (reported below) suggest that this behaviour may arise when the variety is planted outside its normal growing season.

Samples of a number of varieties were sent on request to the following countries:

Ghana	11	samples
French Guinea	77	,,
British Guiana	15	,,
Argentina	1	sample
Cuba	1	,,
Orissa, India	1	,,
Sudan	3	samples

Promising Varieties

These are varieties which have shown promise when grown at Rokupr. They are grown in large plots to make observation of their behaviour easier and in order to produce a reasonable amount of seed to send to sub-stations and to Departments of Agriculture in West Africa for trial. The best of the promising varieties are tested against each other and against established varieties in comparative yield trials. This year the promising varieties were grown at Rokupr in long narrow plots (442 × 6 feet). This system is thought to have two main advantages:

It is possible to rogue each variety without entering the plot and damaging the straw, and therefore estimations of lodging are made more reliable.

Because of the gradient of soil fertility at Rokupr towards the river and because the plots are orientated along this gradient, it is possible to observe the growth of the rice over a wider range of soil fertility than would be possible on a square plot of similar area.

In general the durations were inconsistent, but there was a tendency for them to be shorter than the average values for the last few years.

Some of these varieties have been grown at Rokupr for three years and the following have given consistently good yields: Nachin 11, Radin Siak 34, Subang Intan 117, Radin China 4 and Haji Haroun (from Malaya) and Siam 9 (from Orissa). Pindosein A29-20 (from Burma) and Anak Didek and Morak Sepilai (from Malaya) which

were grown as promising varieties for the first time this year also gave yields of over 3,300 lbs. per acre. Acheh Puteh (from Malaya) and Ngasein Thidat C24-102 which have done well in the last two years were disappointing compared with other varieties this year.

Observations on some varieties were also made on riverain flood plains at Musaia in the north of Sierra Leone. Of those already mentioned Radin China 4, Acheh Puteh and Anak Didek did well as also did MLY B404 (from Burma). This last has been consistently only mediocre at Rokupr. Observations on mangrove land at Shenge Island in the south have shown over the last three years that Ngasein Thidat C24-102, Radin China 4 and Wag Wag (from the Philippines) have done the best. At Rokupr Wag Wag has never done very well.

Two statistical yield trials were laid down at Rokupr. The first trial compared six early rices, of which Lead was included as the standard variety. No variety showed a significantly higher yield than Lead but two, MLY C401 and MLY B404 (from Burma), had significantly lower yields. This experiment was laid down on the same plots as last year's uniformity trial. The use of Analysis of Covariance technique showed that there was a correlation between the pattern of fertility of the land in both years, and when corrected yields were calculated to allow for the differing fertility of the plots no significant difference in yield was shown between Lead and any other variety. Details of this experiment are given in Table 7.

TABLE 7

Yield trial of early varieties

Layout 6 × 6 Latin square.
Plots 15 × 13 feet planted at measured 6 in. spacing 2 plants per stand.
Area of plot harvested ·0033 acre.

Variety	*Mean yield in lbs./acre*	*Corrected yield in lbs./acre*
Faya	1,804	1,774
Lead	1,744	1,696
Maung Nyo B24–92	1,645	1,672
Acheh Puteh	1,630	1,628
MLY B404	1,484	1,541
MLY C401	1,485	1,481
Critical difference (5%)	222	226
Coefficient of variation	11·3	—

In the second trial the standard early maincrop variety Sughandi was compared with five promising varieties of similar duration. No variety gave a better yield than Sughandi, but Subang Intan 117 and Reyong 6 (from Malaya) gave significantly lower yields. These two varieties also gave significantly lower yields than Anak Didek. Details are given in Table 8. This experiment was laid down on plots marked out last year, when the yields on each under the same variety were recorded. Analysis of Covariance was therefore also applied to this experiment. The fertility pattern showed correlation with that of last year and corrected yields were calculated without however affecting the conclusions to any great extent except in the degree of significance. Corrected yields are also shown in Table 8.

As station extension areas have not yet been opened, assistance was given to the Sierra Leone Department of Agriculture in laying down a yield trial on the central riverain flood plains, and six promising varieties

TABLE 8

Yield trial of early maincrop varieties

Layout 6 × 6 Latin square.
Plots 11 × 11 feet planted at measured 6 in. spacing 2 plants per stand.
Area of plot harvested ·0019 acre.

Variety	*Mean yield in lbs./acre*	*Corrected yield in lbs./acre*
Sughandi	2,058	2,025
Anak Didek	1,964	1,961
Radin Siak 34	1,805	1,869
Radin China 4	1,819	1,831
Subang Intan 117	1,627	1,609
Reyong 6	1,614	1,593
Critical difference (5%)	253	229
Critical difference (1%)	346	313
Coefficient of variation	11·6	—

not yet released were included together with six established standard varieties. The rice was drilled mechanically. Details of yield are given in Table 9. D114 had poor germination and the yield is probably low on this account. High significant differences in yield were shown. The top two yielders have shown their superiority over the bottom six, and the third and fourth over the bottom five. Faya (from Nyasaland) and Lead have not done so well but might be included in further trials of this sort.

TABLE 9

Yield trial on riverain flood plains

Layout Randomized Block 4 replications.
Plots 220 yards × 11 feet 8 inches combine drilled at 50/60 lbs./acre seed and 200 lbs./acre superphosphate.
Area of plot harvested ·18 acre.

Variety	*Mean yield in lbs./acre*
Radin Siak 34	1,274
Sughandi	1,243
Toma 112	1,209
Haji Haroun	1,204
Faya	1,037
Lead	969
Serendah	894
Maung Nyo B24–92	867
India pa lil 46	866
B.G. 79	856
Pai Gazo	642
D 114	403
Critical difference (5%)	241
Critical difference (1%)	325
Coefficient of variation	17·5

It is apparent that the use of uniformity trials has resulted in a slightly better assessment of varietal differences, but whether this is worth the extra labour involved is still not quite certain. Twelve small plot uniformity trials were laid down in 1956. From these the two most uniform, as determined by observation, were selected for detailed harvesting and the plot yields recorded. Yield trials will be planted on these plots in 1957.

Milling Experiments

The first experiments carried out with the Minghetti sampling mill showed that the only factor in the size of the grain which is sensitive to the setting of the cone in the mill is grain breadth. The setting of the cone to this measurement, however, is critical if optimum results are to be obtained with each variety. Comparisons between varieties made without altering the setting of the cone are valueless. The mill was therefore calibrated for the complete range of grain breadths which are to be found among the varieties grown at Rokupr. Experiments have also shown that under local conditions the optimum moisture content for milling is between 11 and 12 per cent; below this level the number of breakages increased rapidly, and above this level there is an increase in the number of grains which pass through the machine without the husk being removed. The milling procedure has now been standardized and a 50 gram sample of between 11 and 12 per cent moisture content is milled for four minutes at the appropriate setting of the cone. Tests have been started on all the varieties in the collection. Each variety receives two tests; the first on a sample of raw paddy and the second on a sample of parboiled paddy.

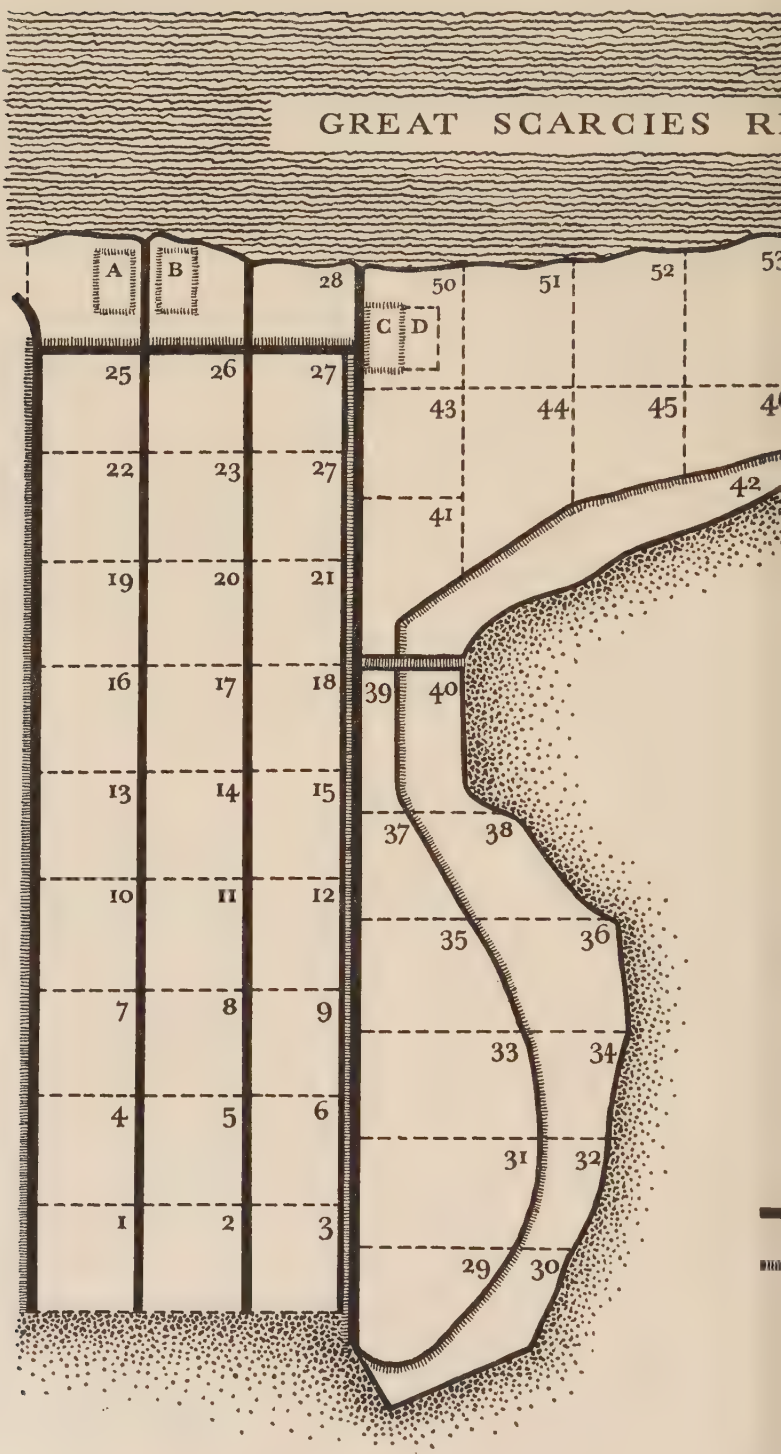
The method of drying rice is known to be a source of variability in the milling results. At present all the paddy is sun-dried, and the rate of drying is therefore dependent on the weather conditions. Too rapid a rate of drying can cause breakage of the grain. Because of this, much time has been spent on the development of a prototype grain dryer suitable for drying the small quantities of paddy required for experimental milling. So far it has been possible to use this prototype to dry nine samples of seed at the same time to 11 ± 2 per cent moisture content. Further improvements are expected when a more suitable fan and heating element, which are at present on order, are incorporated in the apparatus.

SELECTION OF IMPROVED RICES

New Selections

Panianala, a variety which was introduced from Madras in 1931, has recently become popular on the central riverain flood plains of Sierra Leone. These plains are subject to sudden uncontrolled flooding from the rivers. The Sierra Leone Department of Agriculture suggested that selections should be made from this variety, and a sample of Panianala was therefore obtained and grown in a small plot at Rokupr in 1956. From this, thirteen panicles were selected for growing as single panicle cultures in 1957. It is also hoped to make further single panicle selections of this variety on the riverain flood plains in 1957.

A number of single panicle selections of the variety Meike were made in the course of a visit to the Sierra Leone southern grasslands in November. The local farmers use the term Meike (synonym Merikii) to cover a wide range of types of rice—usually awnless with pale yellowish-cream husks, white grain and grown in the less deeply flooded areas. At least two main types can be distinguished—small grain and large grain—the small grained type having a somewhat narrower grain, and this distinction is recognized by some of the farmers themselves. Thirteen panicles were finally selected in the laboratory. The main purpose in making these selections is to establish a few pure lines, representing the better yielding types of Meike, which can be used to test against promising varieties in comparative yield trials designed for the shallower parts of the southern grasslands and similar areas.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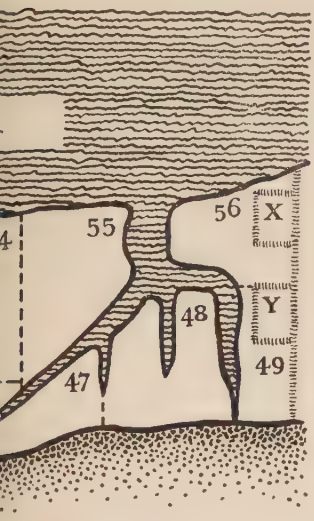

Block	*Variety*
1	D 99
2	D 99
3	Hybrids
4	Selections
5	Selections
6	Hybrids and Experiments
7	Sughandi
8	D 99, Kav. 12 and Lead
9	Collection
10	Sughandi
11	Toma 112
12	Collection
13	Kav. 12
14	Bolo 108 and Indo-China 53
15	Collection
16	Indo-China 53
17	Uniformity Trial and Indo-China 53
18	Collection
19	Promising Varieties
20	Promising Varieties
21	Collection
22	Promising Varieties
23	Promising Varieties
24	Collection
25	Promising Varieties
26	Promising Varieties
27	Collection and B.G. 79
28	India pa lil 46
29	Genetic Stocks and B.G. 79
30	Kav. 12
31	Yield Trial, Experiments and B.G. 79
32	Kav. 12
33	Yield Trial and B.G. 79
34	Kav. 12
35	B.G. 79
36	Kav. 12
37	B.G. 79
38	Kav. 12
39	B.G. 79
40	(Nurseries)
41	B.G. 79
42	B.G. 79
43	B.G. 79 and Uniformity Trial
44	Lead
45	Lead
46	Lead
47	Lead
48	Lead
49	Lead
50	India pa lil 46
51	D 99
52	D 99
53	D 99
54	D 99
55	Lead
56	Lead
A	Sughandi
B	Sughandi
C	Sughandi
D	Sughandi
X	Sughandi
Y	Sughandi

DRAINS

BUNDS

One other selection made this year, also from the southern grasslands, was a single panicle of rice from an exceptionally strong looking plant with large panicles which was noticed among a patch of the local variety Tisei. This plant showed indications that it has the floating habit.

First Year Selections

Of the 54 selections made in 1955 of the Ceylon variety Kurulutuduwi b13, 19 lines were retained after examination of the field characters and flowering curves.

Second Year Selections

Eight out of 31 selections of Kema and nine out of 16 selections of Lath were retained. These two varieties, which are reputed to be resistant to submergence for up to three weeks, were originally selected on the central riverain flood plains of Sierra Leone. All the selection work so far has been based on purity as determined by flowering curves and on general desirable agricultural qualities. Final selection will be made on resistance to submergence, but this work awaits the building of the proposed experimental deep water rice tank.

Third Year Selections

Five out of 19 selections of the floating deep-water variety Mbagboli were retained. The original selections were made on the southern grasslands of Sierra Leone. Further selection of the remaining lines will be considered when the proposed experimental deep-water rice tank is built, and final selection will probably be carried out on the southern grasslands themselves.

Five out of eight selections of the short duration variety D 99 from British Guiana were retained. Final selection will be carried out on milling quality and by comparison with the present genetic stock of D 99.

Sixth Year Selections

Two selections of the variety G.E.B.24 (from Madras in 1931) remained at the beginning of the season. In a comparative yield trial in the previous year no significant difference could be shown between these two lines. This year final selection was made on the better milling quality of G.E.B.24/37.

Seventh Year Selections

Five selections of the early variety Lead (from British Guiana in 1934) remained. These selections had previously been tested in comparative yield trials in 1953 and 1954, when no statistical differences in yield were shown. Final selection of the line Lead 35 was made this year on the basis of milling quality. It remains to be decided whether this line has any special advantages over the present genetic stock of Lead.

Observations were made on the four remaining selections of the early variety B.G.79 (from British Guiana in 1934). None of these selections were discarded as it is thought that further comparison is needed between these lines and the genetic stock of B.G.79, imported from British Guiana in 1952 (F.A.O. Genetic Stock No. 1).

Eighth Year Selections

Three strains of Sughandi (the variety A 28-6 originally imported from Burma in 1936) remained. No significant difference between these strains could be shown in a yield trial in 1955. This year it was found that of these three strains Sughandi 57 shows the best milling quality.

It was decided this year to retain two selections of the local variety Kalimodu for further observation. The third strain was discarded after milling tests.

Older Selections

Two out of 14 strains of the local late main-crop variety, Toma, were selected on milling quality and the remainder were discarded. On this character Toma 281 was the best, but as Toma 112 was a close second and has been the standard genetic stock of this variety distributed, both strains were retained. It is most likely that Toma 112 will continue to be the standard strain distributed from Rokupr as it is known to have particularly good straw strength.

Milling tests were carried out on the ten remaining selections of the local late variety India pa lil. Selection 92 showed the best milling quality, and this strain together with the standard genetic stock India pa lil 46 have been retained for further observation.

The four remaining strains of Pokkali (from Ceylon in 1942), which is reputed to be tolerant to salty conditions, all showed similar milling results and have been retained. It is hoped that these strains will be selected finally on the basis of salt tolerance.

All except one of the four remaining strains of the late variety Kavunginpoothala (from Madras in 1934) have been discarded. The remaining strain Kav. 12, which showed the best milling quality, has been distributed in the past as a standard variety and is maintained as a genetic stock.

Three out of four strains of the deep-water floating variety Indo-China (from French Guinea in 1928) have been kept. Numbers 24 and 70 have the best milling quality, but in the past there have been indications that number 53—which is kept as a genetic stock and is the standard floating rice distributed—has a stronger rooting system and so does better than other strains in areas subject to wash. It is felt that further work is required before a decision is made on these strains.

As there was little obvious difference between any of the three remaining strains of Ngasein (the variety C 19-26 originally imported from Burma in 1936), it was decided to retain number 57 which has been the standard strain distributed and is maintained as a genetic stock.

HYBRIDIZATION

The general policy which has been decided on for handling hybrid material is as follows: no selection of the F1 generation; mass selection from bulk sowing in the next one or two generations; followed by selection of individual plants grown in pedigree lines. It is felt that this policy gives the best compromise between the two systems of selection, the first having the advantage of requiring less work, and the second having the advantage of giving more information. The disadvantages of the first system are minimal in the early generations, and the advantages of the second system are more useful in the later generations.

New Crosses

Four successful new crosses were made this year. The main purpose is to ensure that there is a constant supply of good quality segregating material suitable for West African conditions. It may be thought advisable at a future date to send segregating material to other stations for final selection and purification, e.g., progeny from crosses in the F2 or F3 generations. A common feature of these crosses is that each one is between a local and an introduced variety; it is hoped that by choosing parents which have been selected in different environments and which

have been geographically isolated for some time that a considerable amount of variability will be achieved in the early generations. These crosses are:

X(56)2. Bolo 108 × Ngasein 57. The former is a selection of a Sierra Leone rice and the latter a selection of the variety C 19-26 from Burma.

X(56)3. Toma 112 × Indo-China 53. The former is a selection of a Sierra Leone rice with particularly good straw strength and the latter a selection of a floating rice from French Guinea. This cross has been included so that investigations may be started into the inheritance of the floating habit.

X(56)5. India pa lil 46 × Elon Elon. The former is a selection of a Sierra Leone rice and the latter a promising variety from the Philippines.

X(56)6. India pa lil 46 × Mayang Ebos 80. The latter is a promising variety from Malaya.

A cross between an *Oryza sativa* and an *O. glaberrima* variety, which was attempted late in the season, gave no success. It is proposed to attempt a series of such crosses in the coming year.

Hybrids in the F3 generation

X(53)1. Indo-China 53 × Indo-China 24 (both local selections). The object of this cross between two floating deep-water varieties was to combine the better resistance to wash of Indo-China 53 with the reputed somewhat higher yield of Indo-China 24. So far the progeny of this cross have been selected only on their agricultural qualities. Final selection will have to be carried out under deep water conditions. Fifteen single panicle selections were made for growing as pedigree lines next year.

Hybrids in the F5 generation

X(51)1. Yenti (local variety) × DC 39/15 (selection of the variety DC from British Guiana). The 40 single panicles selected from this cross and its reciprocal in 1955 were grown as pedigree lines. Twenty-one single plants were selected this year from the lines that showed desirable characters.

X(51)4. Ngasein 57 (selection of the variety C 19-26 from Burma) × Tai Chu 65 (from Formosa). The 20 single panicles selected last year were grown as pedigree lines. This cross is showing considerable transgressive segregation for a number of characters but especially for straw height. The wide variation in the progeny is probably due to the previous genetic isolation of the two gene populations: Ngasein 57 is an *indica* (tropical) type whereas Tai Chu 65 is a *japonica* (sub-tropical) type. It is usually not easy to obtain fertile hybrids between these two types of rice because of their genetic differences. Lines showing undesirable characters were rejected and nine single plant selections were made from the remainder.

X(51)5. Toma 112 (selection of a local variety) × Ngasein 57. Nine single panicle selections were made from the bulked material of this cross and 12 from the reciprocal cross. These will be planted as pedigree lines in 1957.

X(51)7. India pa lil 46 (selection of a local variety) × Kav. 12 (selection of the variety Kavunginpoothala from Madras). Bulked material of this cross and its reciprocal was grown this year and 15 single panicle selections were made from it for treatment as pedigree lines next year.

Natural Cross Fertilization

At present no estimate is available of the amount of natural cross fertilization which takes place at Rokupr; consequently it is difficult to decide to what extent precautions should be taken to ensure a high probability of self fertilization in maintaining pure lines. Estimations have been given of the percentage of cross fertilization which takes place in various countries, and it would seem that there is a big variation with environment. An experiment laid down at Rokupr in 1953 gave no useful results. A further experiment was therefore designed to try and find a method of investigating the amount of cross fertilization which occurs at Rokupr. The experiment involved sowing patterns of two varieties: D 99 with the dominant character red apiculus, and Lead with the recessive character white apiculus. The intention was to study the proportion of red to white apiculus in the F1 generation of Lead. However, in spite of repeating the experiment three times, in each case using a different sowing time for one of the varieties, synchronous flowering was not achieved. The experiment was therefore abandoned, though the experience gained has been helpful in the redesign of experiments to be carried out in 1957.

PHYSIOLOGICAL WORK

Factors affecting Flower Opening and Anthesis

Daily opening of rice flowers at Rokupr usually occurs some time between 10 a.m. and 1 p.m. G.M.T. (sun time at Rokupr is approximately 50 minutes later than G.M.T.). The prediction of the time of flower opening on any particular day would simplify the work involved in carrying out hybridization. Using Rhind's method of emasculation it was found in 1951 that the best time to force open the flowers in order to be able to carry out the emasculation was about half an hour before the flowers open naturally.

In order to find out whether the time of flower opening can be correlated with any meteorological data, detailed observations were made on the following variables from 8 a.m. to 1.30 p.m. on eight different occasions spread over a period of nearly four weeks during October: temperature, relative humidity, incident light intensity and wind speed. The thermohygrograph (frequently checked against wet and dry bulb thermometers when the wind speed was suitable) which was used for the recording of the temperature and humidity was housed in a meteorological screen within a few feet of the observation plots and at the same height above the ground as the panicles. Records of the light intensity (made with a Weston Master II exposure meter with an Invercone attachment) and estimates of the wind speed were made by an observer at 15-minute intervals until the opening of the first flower, and thereafter at five-minute intervals. Four varieties were used for study: Lead, HR 22, Tai Chu 65, and Sitpwa C28-15. These were planted in observation plots each a yard square. The time at which the first flower on each panicle began to open was noted to the nearest five minutes.

The plant to plant variation within a variety was found to be considerable; frequently three hours elapsed from the time the first panicle started flowering until the last panicle started, and when the results were graphed no well defined period of maximum flowering was usually detectable. Therefore no correlations between flowering and meteorological data were apparent. It was suggested in 1951 that flower opening occurs when the temperature rises to about 83 °F.; however, during the the present observations, it was noticed on one occasion that flowering

occurred within the normal period when the temperature did not rise that day above 80 °F. It would seem therefore that the time of flowering is not closely controlled by any of the more obvious meteorological factors, though they may have some slight modifying influence on the diurnal rhythm of flowering.

Anthesis was observed to occur a few minutes after each flower opened. As would be expected, this occurred more quickly on good drying days, i.e., when the sun was out, temperature high, humidity low and a breeze was blowing.

Factors affecting the Duration of Rice Varieties

One of the problems encountered when exchanging rice varieties with other countries is that the time taken from sowing to harvest often changes in a new environment. Certain varieties have been shown to be sensitive to photoperiod (the relation between the lengths of alternating periods of light and darkness). The so-called " date fixed " varieties are probably all photoperiodic. On the other hand certain varieties always take approximately the same time from sowing to harvest no matter at what time of the year they are grown, and it is probable that nearly all of these " period fixed " varieties are insensitive to photoperiod. However, it has been noticed that a number of varieties—probably the majority—do not behave as though they are date fixed or period fixed; in other words duration can be altered by the time of planting but the rice does not flower on the same date irrespective of planting time. In these cases it is possible that characters other than photoperiodism influence duration.

The present experiments were designed to investigate those factors other than photoperiodism which may influence duration. As a working hypothesis it was decided that two important factors might be light intensity and temperature. Nine varieties were chosen for experiment: three reported to be sensitive to photoperiod—Bentoubala B (from French Sudan), Radin China 4 (from Malaya) and Podiwi a8 (from Ceylon); three varieties reported to be insensitive to photoperiod—Tai Chu 65 (from Formosa), Radin Siak 34 (from Malaya), and Co. 25 (from Madras); and three varieties with unknown response to photoperiod—Lead (from British Guiana), Toma 112 (from Sierra Leone) and Wag Wag (from the Philippines).

Two main experiments were carried out. The first involved the successional sowing of each variety at fortnightly intervals over a period of 28 weeks. In the second experiment each variety was subjected to four treatments; three different degrees of shading with wooden lattices and a control where the plot was left unshaded. Tiller counts were carried out on both experiments at regular intervals, and dissections were also carried out on sample plants at regular intervals in order to determine the time at which the apical meristems changed from vegetative to sexual primordia.

The results of these experiments, which it is intended to continue and extend, will be reported in detail at a later date, but the main results may be summarized as follows. In every variety light intensity affected duration in the same way: the heavier the shading the greater the delay in flowering. However, the degree of the response varied with the variety, and in general it was greatest in those varieties which had the shortest duration. Shading also decreased the rate of tiller formation and the final number of flowering tillers formed. Only one variety, Tai Chu 65, showed strong " period fixed " behaviour; all the others were influenced by the time of planting and are probably influenced to varying extents by photoperiod. Temperature was recorded throughout the experiments by means of a thermograph in a meteorological screen

set three feet above ground level. Such factors as total temperature throughout the growing period, day temperature, night temperature and the diurnal range have all been considered but it has not been possible to demonstrate that any of them have affected duration, though it cannot be certain that in some way temperature does not affect duration. Certain factors of agronomic importance have been brought to light by these experiments: for instance, the importance of planting at the right time to obtain maximum tillering and least plant-to-plant variability with regard to time of flowering. This last factor is important in order to obtain evenness of ripening, and it is also important to consider it when uniformity of flowering is used as a criterion for the judgment of genetic purity.

Dormancy and Viability of Rice Seed

New introductions of rice varieties are grown at Rokupr in observation plots for about two to four years. After this period a decision is made as to which of the following three categories they should be assigned:

(i) Of no value. Discarded.
(ii) Promising. Grown as a promising variety in a larger plot and tested against standard established varieties in yield trials.
(iii) Not immediately useful, but the variety has certain characters which might be of use in a future breeding programme.

Under the present practice the varieties in category (iii) are grown every year in small maintenance plots in order to ensure a stock of viable seed. This is necessary because the viability of most rice varieties falls off rapidly under normal storage conditions. It would be useful therefore if a simple method of storing rice seed for long periods and yet maintaining viability could be found; this would reduce the cost in land and labour required to look after a large maintenance collection, and in addition the danger of loss of purity would be minimized.

Although there is considerable literature on the storage of rice for use as food in which case it is not necessary for the seed to remain viable, there is not a great deal of published work on the storage of seed rice. Recent work by Dore in Malaya has shown that the longevity of rice seed can be increased by lowering the temperature and humidity. This work was, however, carried out using fluctuating temperatures and humidities, and furthermore the relative importance of these factors was not determined. It seemed therefore advisable to start work on this problem at Rokupr.

If rice seed is set to germinate immediately after harvest, it is found with most varieties that all the seed is dormant and will not germinate. The period of dormancy varies from seed to seed and the average dormancy period varies from variety to variety, but at Rokupr about three months may be taken as an average period for the maximum germination rate of a variety to be achieved under normal storage conditions. This dormancy characteristic of rice seed is normally agriculturally unimportant in Sierra Leone. It was envisaged that in the future, however, it might be necessary to grow two crops a year of short-duration hybrid rices in order to speed up the work of a breeding programme. (At present it takes approximately ten years from making a hybrid to the release of a proved variety.) An ability to shorten the dormancy period would then become important. For this reason, and because it was argued as a working hypothesis that increasing the period of dormancy might increase the period of viability, and because of the practical convenience of combining the two types of experiment, studies on factors affecting the dormancy period were included in the experiments on viability.

The initial experiments, which are still in progress, have been carried out on four varieties with different durations—Lead, Sughandi, Toma 112 and Kav. 12. These experiments have shown that storage of seeds either in sealed tins at ambient temperature and 11 per cent moisture content or in unsealed tins at a constant temperature of 8 °C. and about 15 per cent moisture content will maintain the viability at approximately 100 per cent germination when under normal storage conditions it has dropped to less than 50 per cent; this happened in just over a year from harvest. Storage at 8 °C. extends the dormancy period (in one variety complete dormancy is still being maintained after 15 months), but storage at 11 per cent moisture content and ambient temperature does not extend the dormancy period. When the period of dormancy is prolonged by cold storage, dormancy may be broken at any time by transferring the variety to storage at ambient temperature. When this is done the curve of the breaking of dormancy (percentage germination plotted against time) is similar to that which is obtained immediately dormancy begins to break after harvest under ordinary storage conditions. Storage under very moist conditions at 8 °C. immediately after harvest causes dormancy to be broken more quickly than under normal conditions. Somewhat surprisingly therefore it would seem that these rices, which are *indica* varieties and therefore tropical, show a similarity with many temperate crops. One of the four varieties, Toma 112 (a local selection), was found to break dormancy more quickly after all conditions of storage if it was subsequently germinated in diffuse daylight; the difference in time compared with germination in the dark was two to three weeks. The other varieties appeared to be insensitive to light.

These experiments with four varieties have now been extended in two ways, firstly by a survey of the dormancy and viability behaviour under normal storage conditions of most of the varieties in the collection, and secondly by a wider range of experiments and more intensive study of one variety (Sughandi) which were suggested by the results of the initial experiments. Some of the factors which are under investigation are: the effect of heat treatments on dormancy; the effect of constant as against fluctuating temperature on viability; the effect of storage in atmospheres of different proportions of oxygen, nitrogen and carbon dioxide on dormancy and viability; the effect of severe dessication on dormancy and viability; the effect of thiourea on dormancy; and initial attempts have been made to extract a germination inhibitor.

Seed Dressings

An experiment has been completed which was designed to show whether three seed dressings used singly or in combination affect the viability of rice seed. The dressings used were Agrosan GN (an organomercury compound), Agrocide Dispersable Powder (containing technical benzene hexachloride) and Didimac Dust (containing 5 per cent technical DDT). The experiment has shown that if the seeds are treated immediately after harvest none of these products has an effect on the percentage germination for at least nine months after treatment (when the experiment was discontinued). However, on germination two months after the dressing of the seed, any treatment containing Agrocide has an adverse effect on the growth of the seedlings immediately following germination: the main symptoms were extremely stunted roots and swollen coleoptiles. This effect becomes more marked with increase in the storage period from the time of treatment. It has been shown, however, by an experiment in which the stunted seedlings were transplanted to soil in pots soon after germination that the seedlings are

capable of overcoming this deformity and their later growth is comparable with other treatments and control plants. Nevertheless, it is felt that it would be extremely unwise to advise the use of Agrocide as a seed dressing. The dressing which is used at present for seed sent abroad is a mixture of Didimac and Agrosan.

Hydroponics and Salt Tolerance

Early in the year, with the co-operation of the Soil Chemist, an experiment was carried out in order to investigate the salt tolerance of 24 different varieties. Each variety was grown in a series of plant pots containing surface mud from the farm and containing six different levels of salt concentration. The salt concentration in each pot was maintained by catching the drainage water in bowls placed beneath the plant pots and using this water, together with any extra fresh water which was required to allow for the loss by evaporation, to water the pots. This experiment has not been reported in detail because the results were too variable for any useful conclusions to be drawn from them. Indications from sampling the mud in the pots and carrying out chloride determinations suggested that part of the variability may have been due to failure in obtaining an even distribution of salt through the mud.

Partly because of the experience gained from this experiment it has since been thought that it would be easier to obtain more controlled conditions for this type of work using culture solutions. Even though the use of this method would not entirely imitate natural conditions, it should prove a valuable technique for carrying out the initial screening of varieties for salt tolerance; the final testing could always be carried out under natural conditions.

Preliminary investigations with nutrient solutions showed that this system of culture is suitable. Aeration is not necessary at least in the earlier stages of growth, but it does have an effect on the morphology of the roots and causes a greater degree of branching.

Further investigations await the arrival of apparatus which will enable experiments to be carried out on a larger scale.

DISEASES

Piricularia oryzae occurred as usual in the nurseries. The attacks were, however, unimportant except in the case of two small nurseries of Sughandi where the seedlings were completely destroyed.

Helminthosporium oryzae (the imperfect stage of *Cochliobolus miyabeanus*) also occurred as usual in the nurseries without causing any real damage. Six rice varieties which arrived and were planted late in the season were also attacked by this fungus in the flowering stage, but the attack was only slight. These varieties were Malobadian, Ca/446/633121, R.69, 4 Mezes, Iguape and Pratao. They were planted in adjacent plots.

Ephelis pallida occurred only on the variety Lead on Block 41 this year. The attack was only very slight. It is the first time that this fungus has been recorded on this variety of rice.

SOIL SCIENCE

The development of certain mangrove soils for rice growing presents special problems. Although it has been possible to reclaim large areas of mangrove land by clearing and cultivating under tidal conditions, there are still soils in saline coastal areas and saline reaches of rivers which cannot be developed without recourse to empoldering. Experience in Sierra Leone has shown that empoldering these areas, with the consequent drying out of the land in the dry season, is not practicable owing

to toxic conditions which then develop in these soils. Research has therefore been concentrated on a study of the characteristics of mangrove soils, both chemical and micro-biological, which must be considered in their agricultural development. Information on the problems involved should be applicable also to the development of mangrove land in Eastern Nigeria, where partial control of water could be of use in obtaining the correct soil conditions for mechanical cultivation and other operations.

CHEMICAL CHARACTERISTICS OF ACID MANGROVE SOILS

Routine Soil Investigations in the Rokupr Experimental Polders

The routine observations which were reported in the 1955 Annual Report have been continued. Soil samples were taken at monthly intervals from the surfaces of the four plots of the experiment designed to investigate the effect of different systems of water control on the fertility of empoldered areas, and from five other sites on Rokupr farm, and the pH values were determined. In addition determinations were made of the levels of availability of the following ions: iron, aluminium, manganese, calcium, magnesium, potassium, phosphate and chloride. Standard techniques were used. Chloride was determined in aqueous extract. The levels of the other ions were determined in extracts prepared by treating the soil with solutions of ammonium acetate, the pH values of which were adjusted to be approximately the same as those of the soil samples.

The following conclusions can be drawn from the results of these observations:

(*a*) The low yield of rice in polder C of the experiment, which has been completely excluded from tidal wash since 1946, may be accounted for by the high acidity of the surface soil. Polders A and B, from which the tide has been excluded for only a part of each year, and polder D, which has been under tidal conditions throughout, had less acid surface soil and gave good yields of rice.

(*b*) A fairly regular seasonal pH fluctuation of about three units occurs in the surface soil of the experimental areas. The value is higher in the wet and lower in the dry seasons.

(*c*) This large seasonal variation in the acidity of the surface soil does not occur over the farm as a whole and appears to be confined to soils which formerly carried mangrove vegetation. There are indications, however, of a similar smaller variation of about one pH unit over the rest of the farm. The value falls slowly until the end of the dry season and then rises rapidly.

(*d*) The large variations in the value of the soil pH in the experimental areas are accompanied by large variations in the levels of availability of iron (6,400 to 0 parts per million wet soil) and of aluminium (430 to 0 parts per million). They are also accompanied by variations in the level of availability of phosphate (40 to 1 parts per million), but there are smaller variations in the level of availability of this ion which are not related to those of the soil pH value.

(*e*) No regular variations in the levels of availability of manganese and magnesium could be demonstrated.

(*f*) The level of chloride in the soils rises slowly during the dry season to between one and two thousand parts per million (wet soil) and falls rapidly when the rains begin to about 40 parts per million. This is probably a result of the variation of the salinity of the river water.

(*g*) There are variations in the levels of exchangeable calcium (600 to 0 parts per million) and potassium (350 to 50 parts per million) which are not related to the variations of the soil pH value. The data available do not make it possible to state the reasons for these variations with certainty, but they appear to be related to uptake of ions by growing plants and decomposition of plant residues and, in the case of potassium, to the salinity of the river water and to water movements in the soil.

The investigations were designed to demonstrate, rather than to explain, the effects, and draw attention to the necessity for care in relating soil analyses to the ability of the soil to supply plant nutrients.

The Mapotolon Empoldering Scheme Survey

During the dry seasons of 1954 and 1955 studies were made of the soils of the empoldering scheme at Mapotolon to determine whether correlations exist between various soil factors and the growth of rice. No satisfactory correlations were found and in 1956 the method was modified. Whereas in 1955 a single set of soil samples was collected at the end of April, two sets of soil samples were taken in 1956, the soils of the whole scheme being sampled at the beginning of May, and those of one of the two independent polders again seven weeks later at the end of June. The soils were sampled in the same way and in approximately the same places on both occasions as in 1955. The samples were examined in a number of different ways in 1955, but in 1956 the only determinations made were those of pH values of all the samples on each occasion, and of the organic matter contents of a third of the set of later samples.

The distribution of surface soil pH values and organic matter contents has been compared with that found in 1955. The two pH distributions are quite similar in outline, but there are some differences in detail. The 1956 samples show a marked tendency for the extension of areas in the pH range 2·5 to 5·0 units. This is most clearly seen in a decrease in the area of the polders having pH values above 5·0 and may be due to upward movement of acidic compounds in the soil. There is also a decrease of the area of those zones where the surface pH is less than 2·5 units; this is most pronounced in the neighbourhood of the least satisfactory length of bund enclosing the polders and may be due to leaching of the soil. The distribution of organic matter is very similar in both years. The most noteworthy difference—an increase of those areas where the organic matter content is between 5 and 10 per cent—might be accounted for by the presence of the residues of the previous year's rice crop.

Comparison of the acidity of the surface soil in May and June shows a marked fall in most areas. This is in agreement with the observations which have been made on the soils of the Rokupr experimental polders and confirms the generality of seasonal surface fluctuations in acid mangrove soils. This fall in acidity is not uniform, so that the distribution in April is not the same as that when the rice seedlings are transplanted into the soils at about the end of July.

The scheme was visited again in November to examine the growth of rice in the polders and to determine whether a correlation existed between rice growth and the fluctuations in acidity which had been recorded. It was found that in areas where the surface soil had been highly acid, either the rice had failed or farmers had left the land unplanted in anticipation of failure. Such areas had shown only small changes in acidity between May and June, suggesting that toxic soil conditions may be related to the ability of the soil to recover from highly acid conditions at the beginning of the rainy season. These areas in which the rice had failed or had not been planted were heavily waterlogged,

and hydrogen sulphide was detected in some places. Heavy waterlogging would prevent the leaching out of acid compounds and recovery of the soils under these conditions could be expected to occur only by the process of sulphate-reduction. This process may be too slow to enable recovery of the soil to take place before planting time, and may result in the accumulation of hydrogen sulphide in volumes too great for complete precipitation as ferrous sulphide.

The effect of Liming and Leaching

Experiments carried out in 1955 and discussed in the last Annual Report showed that rice growth was restricted by the high content of available iron and aluminium in acid soils, and that the limiting soil acidity for good rice growth was pH 5·0. Observations on the soils of the Rokupr experimental polders have suggested that, unless the soil is subjected to leaching, the high concentrations of these ions released in acid soils may not necessarily be reduced by decreasing the soil acidity. Experiments were therefore carried out to determine if this was in fact so, and the effect of liming and leaching on the availability of these ions was investigated. A study has also been made of the economics of the liming of soils of varying acidity.

Samples of a fresh mangrove soil were dried for different periods to give a series of soils ranging from an intensely acid sample of pH 2·93 to a sample having a pH value of 5·01.

Varying levels of liming, and of leaching with distilled water, were applied to such a series of soils and their effects on soil acidity, and on the availability of iron and aluminium, were recorded. The results showed that the amounts of available iron and aluminium were entirely dependent on the acidity of the soil, and that both liming and leaching independently reduced this acidity. The effect of leaching suggests that ridging of acid soils may be a useful and simple procedure for ameliorating soil conditions.

Soil was again dried for varying lengths of time, to form a second series of samples of increasing acidity. The amount of lime required to restore the soil to the level of acidity which allows good rice growth—pH 5·5—was determined for each sample. This was done by direct titration of standard sodium carbonate solution against known weights of soil in a one in four water suspension. This method was standardized by determining the lime requirements of a limited number of soil samples by direct addition of known amounts of lime.

Although the application of laboratory studies to field conditions must be made with caution, the results indicate that liming of acid soils with pH values much below 5·0 would be uneconomic. For example, the most acid soil examined (pH value 2·9) would require about 14 tons of lime per acre, equal in value to about five times the rice crop to be expected in a single year.

THE ROLE OF MICRO-ORGANISMS IN ACID-FORMATION IN MANGROVE SOILS

Preliminary Experiments

When a sample of mangrove soil is allowed to dry in the laboratory, the course of acid-formation in the soil may be followed by daily pH determinations carried out on small representative samples of the bulk sample. Experiments have shown that acid-formation in soils dried under these conditions follows a definite pattern consisting of three phases : a lag phase in which the pH of the soil remains relatively constant, a phase in which the soil pH falls rapidly, and a final phase in which the pH remains at a constant low value or drifts upwards to a

small extent. The constancy of the pH during the lag phase is more marked when measured in a soil suspension of normal potassium chloride than in a water suspension, from which it appears that little change occurs in the concentration of exchangeable acid during this period. Records of the soil moisture content show that moisture is lost from the soil at a constant rate during the lag phase, after which the soil breaks up into aggregates. When this happens the rate of moisture loss is increased, probably due to the increase in surface area available for water loss. It is probable that aerobic conditions are established in the soil at this point in the drying process. In general terms, the process may be similar to that which occurs in acid mangrove soils in the field and which is responsible for the increase in acidity that takes place in such soils during the dry season.

Initial experiments have been carried out in order to determine whether the process of acid formation can be modified by the addition of various substances to the soil. It was hoped that information on the nature of the process might be obtained in this way. The materials added are grouped as follows:

(*a*) Sulphur compounds.
(*b*) Substances likely to act as inhibitors of bacterial activity.
(*c*) Organic materials capable of rapid bacterial decomposition.
(*d*) Various fertilizer materials.

(*a*) The peculiar properties of acid mangrove soils have been attributed to their containing large quantities of sulphides, which may be oxidized to sulphuric acid when the soil dries out. The addition of various sulphur compounds to samples of drying mangrove soil might therefore be expected to modify the process of acid-formation, either by altering the length of the lag period or by influencing the amount of acid finally produced. Addition of sulphides, sulphites and sulphates had no effect. No source of elemental sulphur was available at that time, but thiosulphate, a compound readily oxidized by *Thiobacillus*, did increase the final acidity of the soil to a small extent, although it did not influence the length of the lag phase. In general little modification of the process occurred and the results indicate that the concentration and availability of sulphur compounds, if they are involved, do not limit the formation of acid.

(*b*) If bacteria are involved in the process of acid formation, the addition to soil of chemical inhibitors of bacterial activity might be expected to hinder or reduce the intensity of the reaction. It was found that the addition of 2,4,5-T (2,4,5-trichlorophenoxyacetic acid)—the only possible inhibitor available at the time—had a small effect on the final intensity of the acid conditions produced (about 0·75 pH units). The treatment of the soil with 0·2 per cent sodium azide, a known inhibitor of bacterial activity, doubled the length of the lag phase (from six days in untreated soil to twelve days in treated soil) and resulted in considerable reduction in the intensity of acid formation (from pH 2·5 in untreated soil to pH 3·9 in treated soil). This effect was observed in soil samples treated with azide at any time during the six-day lag period, and addition after eight days still resulted in a considerable reduction.

The results indicate that the process of acid-formation in mangrove soils is the result of bacterial activity and that this activity is not initiated until after the lag period. Inhibition of bacterial activity delays acid-formation and reduces its intensity, suggesting that a chemical reaction is involved which can only occur in drier soils than the bacteriological reaction, and that this chemical reaction appears to be unable to produce such intensely acid conditions as the bacteriological one.

(*c*) If the bacteriological reaction can be inhibited by some soil treatment, considerable amelioration of the soils might result. Addition of

various organic substances was therefore tried, and their effect on acid-formation followed throughout the drying process. It was found in general that rice bran had little effect on the process, though such easily decomposable substances as peptone, glucose and sucrose reduced acid-formation to some extent, possibly by producing competitive effects among the soil population. Peptone in particular reduced the final acidity of the soil samples to a considerable extent and delayed the production of sulphate in the soil. This may have been due to the release of large quantities of ammonia by ammonification during the anaerobic lag phase, the ammonia acting as an inhibitor in a similar way to sodium azide.

These experiments, although by no means conclusive, do indicate that the decomposable organic matter in the soil might be of importance in reducing the intensity of acid-production in soils likely to be too acid for rice growth. Cultivation methods which lead to the presence of readily decomposable organic matter in the soils might be used in conjunction with other methods of amelioration in acid mangrove soils.

(*d*) Addition of various fertilizer materials in quantities practicable on a field scale had little effect.

Sulphur-oxidizing Bacteria and Acid-formation

A dilution technique has been employed to determine the numbers of bacteria present in mangrove soils and capable of oxidizing elemental sulphur with the resultant formation of acid. Estimations carried out at intervals on samples of soil allowed to dry in the laboratory have led to the following results:

(*a*) Potentially acid mangrove soils contain a relatively large population (10^4 to 10^5 per gram of oven dry soil) of bacteria capable of producing acid from sulphur, even when sampled from heavily water-logged situations.

(*b*) This population remains constant during the lag phase of drying, but increases logarithmically from the onset of acid-formation until it reaches a maximum value at about the same time as the soil pH value reaches its minimum. At this stage the number of organisms in the soil was estimated to be about 10^8 per gram of oven dry soil.

The results show that acid formation in mangrove soils left to dry in the laboratory is the direct result of the activities of the sulphur-oxidizing bacteria, and suggest that elemental sulphur is the most likely source of oxidizable material. Whether this material is present in the soil on collection or whether it accumulates during the lag phase has not yet been determined. From the experiments described previously it seems likely that the lag phase is a phase in which the activity of the bacteria is prevented only by the anaerobic conditions which prevail.

Estimations which have been carried out at intervals on samples of soil under field conditions have confirmed these results, and suggest that the increases in acidity which occur in the soils of Rokupr farm during the dry season are also the result of bacterial sulphur-oxidation.

It has been possible to demonstrate the high degree of activity of the sulphur-oxidizing bacteria in potentially acid soils by use of the soil percolation technique. When sodium thiosulphate solution was percolated through freshly collected mangrove soil, sampled during the dry season, the length of time which elapsed before oxidation of the thiosulphate to acid sulphate occurred was small (about 40 hours). A much longer lag (about 70 hours) occurred when thiosulphate solution of the same concentration was percolated through a soil not subject to seasonal fluctuations in acidity.

H. D. JORDAN,
Officer in Charge.

APPENDIX A

METEOROLOGICAL RECORDS ROKUPR—1956

	Jan.	*Feb.*	*March*	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Rainfall	0·00	0·23	0·24	4·93	8·89	23·57	22·91	25·23	20·82	14·24	5·04	2·78	128·88
(20 year average)	(0·13)	(0·05)	(0·42)	(1·86)	(6·80)	(14·18)	(23·23)	(29·38)	(18·00)	(15·09)	(5·52)	(0·66)	(115·82)
Sunshine	259·8	254·6	261·6	233·5	217·8	164·7	100·4	61·3	139·4	213·4	180·8	198·3	2285·6
(15 year average)	(251·0)	(228·8)	(241·3)	(203·7)	(193·5)	(160·0)	(105·9)	(63·3)	(128·0)	(189·0)	(199·5)	(224·4)	(2196·2)
Mean Maximum Temperature	90·4	91·8	92·5	92·3	90·5	86·4	82·7	81·3	85·1	87·4	87·9	86·8	87·9
(15 year average)	(91·1)	(93·0)	(93·3)	(92·9)	(91·0)	(88·2)	(84·3)	(81·8)	(85·4)	(88·4)	(89·0)	(89·5)	(89·0)
Absolute Maximum Temperature	93	98	96	97	96	90	87	87	90	91	92	90	98
(18 year record)	(102)	(101)	(102)	(103)	(101)	(99)	(98)	(91)	(99)	(96)	(99)	(97)	(103)
Mean Minimum Temperature	67·1	69·8	70·5	72·4	72·6	71·9	70·9	71·4	72·3	71·2	71·7	69·2	70·9
(15 year average)	(68·3)	(69·5)	(71·8)	(73·2)	(73·8)	(72·5)	(72·1)	(72·7)	(72·3)	(71·8)	(71·9)	(69·3)	(71·6)
Absolute Minimum Temperature	59	63	66	70	69	69	67	69	68	68	69	62	59
(17 year record)	(55)	(60)	(66)	(66)	(69)	(63)	(60)	(68)	(68)	(68)	(63)	(53)	(53)
Mean Relative Humidity a.m.	90	88	83	89	84	89	90	92	89	86	88	88	88
(8 year average)	(89)	(87)	(84)	(83)	(85)	(90)	(92)	(93)	(92)	(89)	(89)	(88)	(88)
Maximum Relative Humidity a.m.	100	95	95	100	100	100	100	100	95	100	100	100	100
(8 year record)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)
Mean Relative Humidity p.m.	76	57	50	83	65	72	79	82	76	68	67	58	69
(8 year average)	(55)	(48)	(52)	(62)	(66)	(73)	(80)	(84)	(80)	(71)	(68)	(56)	(66)
Minimum Relative Humidity p.m.	31	32	36	60	39	54	59	61	59	44	57	29	29
(8 year record)	(20)	(16)	(25)	(32)	(39)	(54)	(59)	(53)	(51)	(41)	(40)	(10)	(10)

Rainfall in inches. Sunshine in hours. Temperature in degrees Fahrenheit. Relative Humidity as percentages. Morning readings taken at 09.00 hours. Afternoon readings taken at 1.500 hours. Bracketed figures are averages and records.

APPENDIX B

RICES INTRODUCED—1956

From India

Prosadbhog	ex Assam
Ambomohor 157	ex Bombay
Ambomohor 159	ex Bombay
Mambilia	ex Coorg
Basmati 370	ex East Punjab
Bhondu X Parewa 116	ex Madhya Pradesh
B 76	ex Orissa
Bansi T 22A	ex Orissa
Anjana	ex Uttar Pradesh
T 23	ex Uttar Pradesh

From Indo-China

Nep Hoa Vang 830	ex North Viet Nam
Nep Ca Cuong 728	ex North Viet Nam
Tieu Be R 13	ex South Viet Nam
Nep Trung Vit G 5	ex South Viet Nam
Cadung Phen R 92	ex South Viet Nam
Bong Sen Den 2 R 10	ex South Viet Nam
Tau Binh CF 18	ex South Viet Nam
Mon Tay Trang BR 11	ex South Viet Nam

(via Senegal)

Kaun-Khum	
Samsep Leau	
Angkor	
Chnourth	
Dang-Dao	
Khoe-Soth	
Krachek-Chap 1	
Phar Comen	
Neang-Nam K 425	
Neang-Ven 20	
Hop-Va	
Sarr-Veng	
Bong-Tom 4480d	
Pharomdeg	
Babo-Thi	ex Viet Nam
Bong-Thanh	ex South Viet Nam

(via French Guinea)

Ba-That-Nho	ex South Viet Nam
Kaum-Kack	ex Cambodia
Tun-Sart	ex Cambodia
Pok	ex Cambodia
Kading-Than	ex Cambodia
Neang-Krang	ex Cambodia
Sar-Kaun	ex Cambodia
Chang-Koum	ex Cambodia
Hamtang P 27	ex Cambodia
Hamtang P 260	ex Cambodia
Kaun-Trei	ex Cambodia
Kracheck-Cheas	ex Cambodia
Neang-Chok	ex Cambodia
Neang-Sar	ex Cambodia
Say-Bourh	ex Cambodia
Tang-Sang-Kor	ex Cambodia
Pamkea-Prom	ex Cambodia
Sar-Sakaw	ex Cambodia
Naang-Sambey	ex Cambodia
Chankong-Kras	ex Cambodia
Neang-Leay	ex Cambodia
Neang-Keth	ex Cambodia

From Formosa

Hsinchu 50

From Java

Lati Sail 509

From Thailand

Peykeo E 53

(via India)

Champa 133
Kod Phom
Mali Ong
Mali Thong
Khao Med Lek

(via Senegal)

Paung Ngeon

(via Tchad)

Tun Sart (Siam)

From Ceylon

Dewaredderi 26081

From Belgian Congo (via French Guinea)

R 69
CA/446/b33121
C/49/22/22

From French Equatorial Africa (Tchad)

Tchad Ca 902/b/2/1
Tchad Ca 902/b/2/2
Tchad 415
Tchad 223

From French Sudan

Sikasso H
Metre Ouoro

(via French Guinea)

Lalande

From French Guinea

Malobadian
Kaolaka
Lisboa
Bandioulou
Birado
Koya
Minikoui
Tagnan
Bogari Gbeli
Makoto
Fossa
Kobomba
Sassiguile
Aboukouye
Malock
Mercainy
Maronkoi
Safigle
Bandiounifing
Malefike
Iontana
Indochine de Kankan
Mercainy Ouaka
Matini
Kourkoussom
Matemine
Simbegni
Yaye

From Senegal (Casamance)

Ecombouka
Kamossor
Doutamano
Etabalica
Diambarang
Ebandioul Yafite
Djilambou
Etomolong
Boumar
Essobao
Niamoune
Sambeugeury
Marie Sagna
Riz Casamance
Coling
Massily
Diamisse
Farafato
Botaly
Messing

From Ghana

Biribra E 37
Jansusu E 32
Mendii E 31
Bawku White E 42

From Gambia

Manifingo
Chawo

From Brazil (via French Guinea)

Iguepe
4 Mezes
Pratao
Amarelao